Auto Segmentation of Oil Slick in RADARSAT SAR Image Data around Rupat Island, Malacca Strait

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KEY WORDS: SAR image, oil slick detection, Bayesian approach.

ABSTRACT

As one of major tankers routes in Indonesia, Malacca Strait is potentially prone to oil spill pollution. SAR image data is used to detect oil slick on sea surface, because of its capability for large scale of sea monitoring, and to solve clouds covering problem in Indonesia. Oil slick is visible on SAR images as dark patches, because it decreases the radar backscatter on sea surface, which is explained by Bragg scattering theory. This project proposes the procedure for auto segmentation of oil slick in SAR image data. To reduce speckle in SAR image, we used the Bayesian approach with *maximum a posteori* filter with assumption that radar reflectivity and speckle noise follow Gamma distribution. This technique is compared with another adaptive filter such as Lee and Frost filter, which shows the best result on reducing speckle on whole area with the lowest ratio of mean and standard deviation, reducing the bright fleck on oil area, and showing the continuity on oil slick and sea area, which is make easier in feature extraction of oil slick. Maximum entropy technique is used for feature extraction on oil slick segmentation with assumption that only two moments are to be determined i.e. oil slick and sea area. It shows the best performance on oil slick segmentation among the others co-occurrence techniques. The area classification between oil slick and look-alike area on low wind area is done based on these result. Usually, low wind areas are located near coastal line. Therefore, coastal line is applied as boundary condition. Coastal line is detected with Canny filter using first derivative of Gaussian as edge detector and mark the position of edge where the gradient is local maximum. Finally, if areas are captured near coastal lines, these areas are marked as the possible looks-alike area.

1. INTRODUCTION

As the largest oil production country in South Asia and OPEC member, Indonesia having oil production both onshore and offshore, as well as refining, and shipping activities. To meet the demand of domestic and other countries, oil production from onshore and offshore refineries are being delivered through major shipping channel at Malacca, Makassar and Bali/Lombok, which make these areas are potentially prone to oil spill pollution [1]. Therefore, SAR image data is used to detect oil slick on sea surface, because of its capability for large scale of sea monitoring, and to solve clouds covering problem in Indonesia.

Oil slick is visible on SAR images as dark patches, because it decreases the radar backscatter on sea surface, which is explained by Bragg scattering theory. The area with lower backscattering value appears darker in radar images. The information of each pixel in SAR image is carried by radar cross section (RCS) or backscattering coefficient, σ^0 in dBs. SAR image is affected by speckle, a noiselike with random bright and dark pixels produced by radar waves due to the different distance of travel from targets or multiple bounce scattering. Speckle influences the ability to estimate image properties and information retrieval from SAR image [2]. Therefore, it is important to apply filter for speckle reducing without losses edge and texture information, which is inevitable on oil slick segmentation. We are proposing the procedure for oil slick detection in RADARSAT SAR image data, based on Bayesian approach with *maximum a posteori* filter to reduce speckle on image with assumption that radar reflectivity and speckle noise follow Gamma distribution, combined with entropy technique for feature extraction on oil slick segmentation and coastal line detection with Canny edge detector on dark area classification.

2. METHODS

2.1 Speckle Filtering

SAR image data consist of RCS, which is affected by speckle, a random distribution of scattering elements. Speckle influences the ability to estimate image properties and information retrieval from SAR image. Adaptive filters based on appropriate scene and speckle model are the most appropriate filter for SAR image because it preserves edge and textural features. These filters, such as Lee filter, Frost, etc., used multiplicative speckle model and local statistic [3]. On this paper, Bayesian inference is applied as the basis of speckle filtering to improve image quality for better estimation than those filters above. The probability density function (PDF) is modeled by using Gamma MAP distribution model [2], as follows:

$$P_{AP}(s \mid I) \; a \; P(I \mid s) P_s(s) = \left(\frac{L}{s}\right)^L \frac{I^{L-1}}{\Gamma(L)} \exp\left[-\frac{LI}{s}\right] \left(\frac{v}{m}\right)^v \frac{s^{v-1}}{\Gamma(v)} \exp\left[-\frac{vs}{m}\right] \tag{1}$$

where, $\hat{m} = \bar{I}$, $\hat{v} = 1/\bar{V}_s = (1+1/L)/(\bar{V}_I - 1/L)$, I is the intensity of pixel, μ is the mean value of distribution and v is order parameter. The difference of observed mean value indicates radiometric distortion. Meanwhile the standard deviation is an estimate of the reconstruction of backscattering coefficient.

2.2 Segmentation of Oil Slick Area

Texture analysis has been extensively used to classify remotely sensed images. Filtering features and co-occurrence have been compared in several studies, which concluded that co-occurrence features give the best performance [4]. Co-occurrence technique use spatial gray level difference based statistics to extract texture from remote-sensed images. Gray level difference of image is defined by,

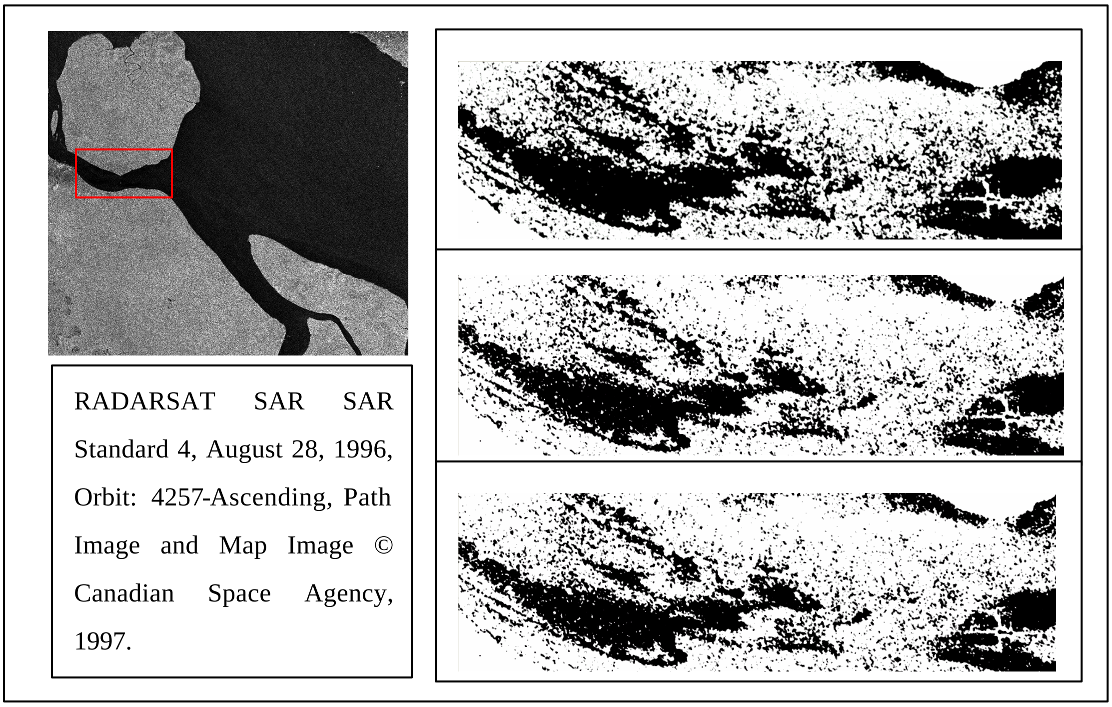
$$G_{\delta,\theta}(m,n) = |G(m,n)-G(m+\Delta_m,n+\Delta_n)| \tag{2}$$

where, Δ_m and Δ_n are integers with $-d\leq\Delta_n$, and $\Delta_m\leq+d$ and $\theta = 0, \pi/4, \pi/2, 3\pi/4$, when d=1. From above equation histogram is calculated as follows:

$$h_{d,q}[i] = \sum_m \sum_n count(G_{d,q}(m,n) = i) \tag{3}$$

Therefore this histogram function can be used to calculate statistic of image with G is number of gray level in image and P is total number of pixel pairs that are separated by distance δ in direction θ. Since there are only two moments to determine from image i.e. oil slick and sea area, the important point that should be measured is the optimum sensitivity with maximum entropy by using following equation:

$$Entropy(d,q) = -\sum_{i=0}^{G-1} \frac{h_{d,q}[i]}{P} \log\left(\frac{h_{d,q}}{P}\right) \tag{4}$$



(a) (b)

Figure 1. (a) Original RADARSAT SAR image data (b) Segmented image with Gamma MAP (μ=2.095864, SD=0.35676), Lee (μ=2.144369, SD=0.248213) and Frost filter (μ=2.152917, SD=0.216861), from top to down

2.3 Classification of Dark Area

Low wind area on sea surface can produce dark area, a look-alike slick area on image. Usually, this area is located near coastal regions [5]. Before classifying dark areas, the coastal line is computed before it applied as boundary condition. We detect coastal line by Canny edge detector. Since it also uses threshold technique on edge detection approach, it easier on locating oil slick area. This edge filter use first derivative of Gaussian as edge detector and smooth the image then mark the position of edge where the gradient is local maximum [6]. The thresholds are applied to decrease the probability of streaking. The Canny edge detector filter is applied with three criteria: (a) good detection of edge with low probability of failing to mark real edge points or falsely marking non-edge points, (b) good localization which the points marked by operator should be located to the center of true edge and (c) one response to a single edge. The criteria, output-to-signal ratio on real edge detection and localization are described as follows:

$$SNR = \frac{\left|\int_{-w}^{+w} G(-x)\, f(x)dx\right|}{n_o\sqrt{\int_{-w}^{+w} f^2(x)dx}}; \quad Localization = \frac{\left|\int_{-w}^{+w} G(-x)\, f'(x)dx\right|}{n_o\sqrt{\int_{-w}^{+w} f'^2(x)dx}} \tag{5a,b}$$

where, G(x) is step edge, and f(x) is the filter.

The typical feature of oil slick also has slight differences with looks-alike area. Then, if dark areas are captured near coastal line, these areas have a possibility to be a non oil slick area.

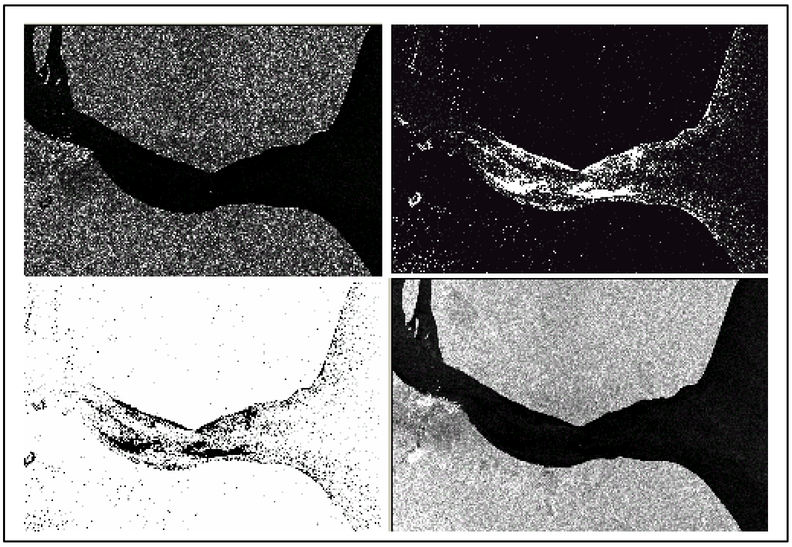


Figure 2. Feature extraction with Co-occurrence technique, from top to bottom: Contrast, Angular Second Moment, Entropy and Mean Method.

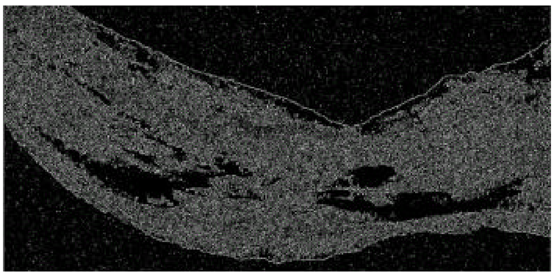


Figure 3. Coastal lines detection result.

3. RESULT

The result shows that Gamma Map combined with entropy technique is the best on reducing speckle on whole area with the lowest ratio between mean and standard deviation, reducing the bright flecks on oil area, and also showing continuity on border between oil slick and sea area, which is make easier in feature extraction of oil slick (figure 1, 2). Meanwhile coastal lines can be detected with Canny filter as shown in figure 3, since it marks the position of edge where the gradients are local maximum. Oil slick areas appear as dark streak on the middle of the strait. Meanwhile, on top right and left in image, the low wind areas appears near coastal line. On the classification between area of oil slick and a look-alike area, the areas on are marked as the possible looks-alike area.

4. CONCLUSION

Oil slick appears as dark feature on SAR image because of dampening effect of Bragg wave that decreases radar backscatter. A Bayesian learning on despeckling process in SAR image using Gamma MAP is proposed for better quality of image with preservation of edge and textural feature. The entropy technique for feature extraction of oil slick area, so far, shows the best result among the other techniques, which use assumption that optimum sensitivity of two moments on sea area is measured. The criterion of Canny edge detector can be used to detect the coastal line and the feature of oil slick. The future works directs towards improvement of classification between oil slick area and look-alike area. Real time wind data also can be useful to provide better result over the area of interest.

ACKNOWLEDGMENTS

RADARSAT SAR images had been obtained as courtesy of ADRO 630 project.

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